Compressed Air

DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

VOL. II. NEW YORK, MARCH, 1897. No. 1

From HARPER'S WEEKLY. Copyright, 1896, by Harper & Brothers.

THE HARDIE AIR MOTOR ON THE ELEVATED RAILROAD, NEW YORK.

Compressed Air

A MONTHLY PUBLICATION DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

W. L. SAUNDERS, - - - Editor and Publisher
A. E. KENNEY, - - Managing Editor
J. E. QUINTERO, }
F. C. WEBER, } - - - - - Associates

Subscription, including postage, United States, Canada and Mexico $1.00 a year. All other countries, $1.50 a year. Single copies, 10 cents.

Advertising rates furnished on application.

We invite correspondence from engineers, contractors, inventors and others interested in compressed air.

All communications should be addressed to COMPRESSED AIR, 26 Cortlandt St., New York.

London Office, 114a Queen Victoria Street.

Those who fail to receive papers promptly will please notify us at once.

Entered as Second-Class Matter at the New York, N. Y., Post Office.

VOL. II. MARCH, 1897. NO. 1.

We present in this issue the case of Pneumatic Traction as it stands up to date. Special attention is called to the facts and figures given by Mr. Pettee in the paper entitled, "Cost of Operating Air Cars in New York City." That the Hardie air motor represents an advance in street car propulsion by compressed air, will, we think, be generally admitted. One of these cars has been in continuous operation in New York since last August, carrying passengers, and to all outward appearances differing but little from the regular cable and electric cars. This is the first time that a compressed air car has done regular and successful commercial service in America for any length of time. All previous attempts may be classed as experimental and it is a fact worthy of notice that these experiments have usually failed to produce permanent results, not because of mechanical failures but owing to lack of funds. To develop a new system of power for tramways is an undertaking which involves a large expenditure of money. Those who are familiar with the early experiments with the trolley know how expensive it was to get started, and what an enormous amount of money was consumed in experiments before commercial success was reached. The late Mr. Franklin Leonard Pope said that compressed air traction would now be successful, had there been spent upon it even a fractional part of the money and brains that have been used in the development of electricity as a motive power for street railroads. Electricity has always been popular as an investment. Its marvelous success in the telegraph, telephone and elsewhere led capitalists to contribute largely toward its use for street cars, and its final success was the result of the strong combination of capital and brains, which combined steadily and faithfully through so many years.

It is only during recent years that the storage system of compressed air traction has been made practicable. A successful storage system involves an air compressor capable of economically producing air power at a pressure of about 2000 lbs. per square inch. In order to do this economically, compound compression becomes necessary. The modern high duty compound compressor consists of four cylinders compressing in four stages with intercoolers between each stage. A Corliss engine furnishes the power and the air is delivered at 2500 lbs. per square inch, and at a temperature about equal to that in the initial stage. The heat loss, that is the loss of power due to the heat of compression, which at these high pressures with single stage compressors was as high as 50%, is now brought down to 17%. In addition to this, the Corliss mechanism produces a H. P. with an evaporation of less than 16 lbs. of water, consuming less than 2 lbs. of coal. After compression the air is stored in tubes which are made of solid ingots of mild steel free from welds and capable of standing pressures as high as 4000 lbs. per square inch. It is only during recent years that these storage reservoirs have been brought to the point of absolute safety. Thus we see that air power may be produced and stored safely and economically, and as compressed air is capable of driving an engine designed for steam power, the problem resolves itself to a common reciprocating engine as a motor to drive the car. For the sake of economy the air motor is of special construction, using hot air and cutting off early in the stroke, expanding and exhausting at atmospheric pressure.

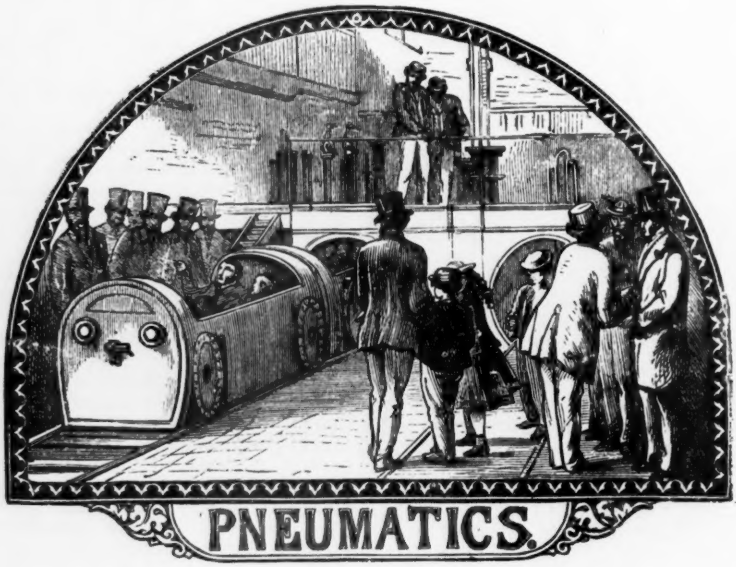
HISTORY.

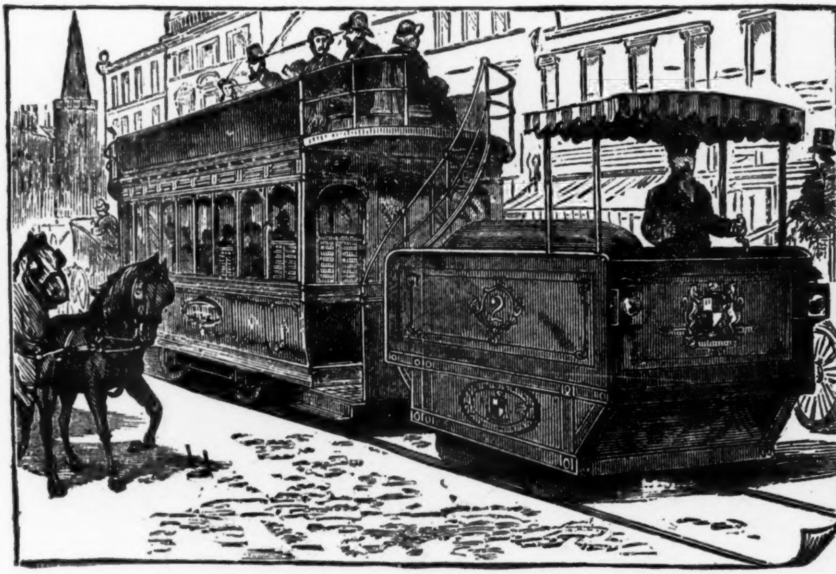
From historical research it appears that compressed air for conveying passengers has always been under consideration. Nearly all experiments have served to prove the mechanical power of the atmosphere; and the question, how it could be converted into a motive power, available for the conveniences of society, has been a problem of great interest to engineers. More than two centuries ago the notion was entertained of producing motion economically for the purpose of transit by means of the pressure of the atmosphere. The original thought may at least be traced back with certainty to the celebrated Dr. Papin. In the year 1810, a proposal was made by Medhurst, the Danish engineer, to put letters and goods and passengers in a canal, 6 ft. high and 5 ft. wide, and containing a road of stone and iron, and project them by means of atmospheric rarefaction and condensation.

In 1824, an Englishman, Mr. Vallance, made a similar suggestion. His daring plan was to connect Brighton and London by means of an enormous tube, through which, by pumping out the air, carriages were to be propelled with the velocity of a cannon ball. Other plans of equally novel character were considered at various periods.

The Pneumatic Parcel Despatch Company, of London, about the year 1865, successfully worked a pneumatic line while it was designed for parcels, was capable of carrying passengers. (See illustration.)

The construction of the tube between Euston Square Station and the Northwestern Post Office in Eversholt, is described as most simple, cheap and effective, and reflected great credit upon its engineer, Mr. Rammel, for the ease and certainty with which the air from the *fans* sends one or more carriages, heavily laden, from one end to the other. Other demonstrations were made on this same line. At the Polytechnic of London, a little model of wood was constructed about 20 feet long. There were two carriages; the passengers consisted of a party of white mice, and they were blown from one end to the other by means of a blast of air.





TRIAL OF THE BEAUMONT COMPRESSED AIR MOTOR AT WOOLWICH ARSENAL, ENGLAND.

Recent Experiments in Compressed Air Motors.

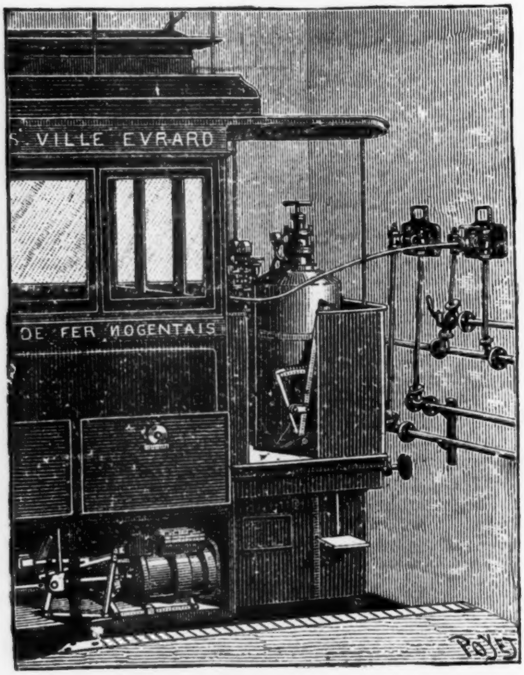
In 1880, it was thought Col. Beaumont, R. E., of England, had effected a locomotive that had mastered the problem of compressed air for traction purposes. The construction of the engine was based upon the principle of utilizing the entire power stored up in compressed air, no matter how high the pressure should be. This was effected by admitting the air into successive cylinders, having different areas, commencing with the smallest, and in making provision by which, as the pressure fell in the reservoir the consumption of air can be increased. In appearance the engine differed from an ordinary locomotive, the absence of a funnel or other outlet for smoke or steam being a prominent departure.

Col. Beaumont was allowed by the British Government to experiment in the Royal Arsenal, Woolwich.

A difficulty met with in the Beaumont method, was the tendency to produce extreme cold, which became condensed and frozen on the working parts. Reports of tests however, show that very good results were obtained.

The First Street Railway.

The first ancestor of the street railway was the tramway. Tramways were first introduced in the coal mining districts of the North of England, between the years of 1602 and 1649. They consisted of parallel lines of wooden trams or beams, pinned down to the ground, with flanges on them, and not on the wheels as now. Coal wagons were drawn to and fro along these flanged trams from the coal pits to the shipping ports. The first use of iron on these tramways was in 1767, when cast iron plates were nailed down on timbers to protect them where they wore out the fastest. The plates or rails, were cast in sections five feet long, four inches wide and an inch and a half thick. All iron rails were cast until rolled wrought-iron rails were introduced in 1820. The width of the tramways was about four feet, eight and one-half inches, because that happened to be the usual width of wagon tracks in that region. Horse railroads of a crude type were in use in England in 1805. We find in that year five were chartered by act of Parliament; sixteen were chartered in 1815, and thirty-two in 1825. After that it seems to have become a lost art in Eng-



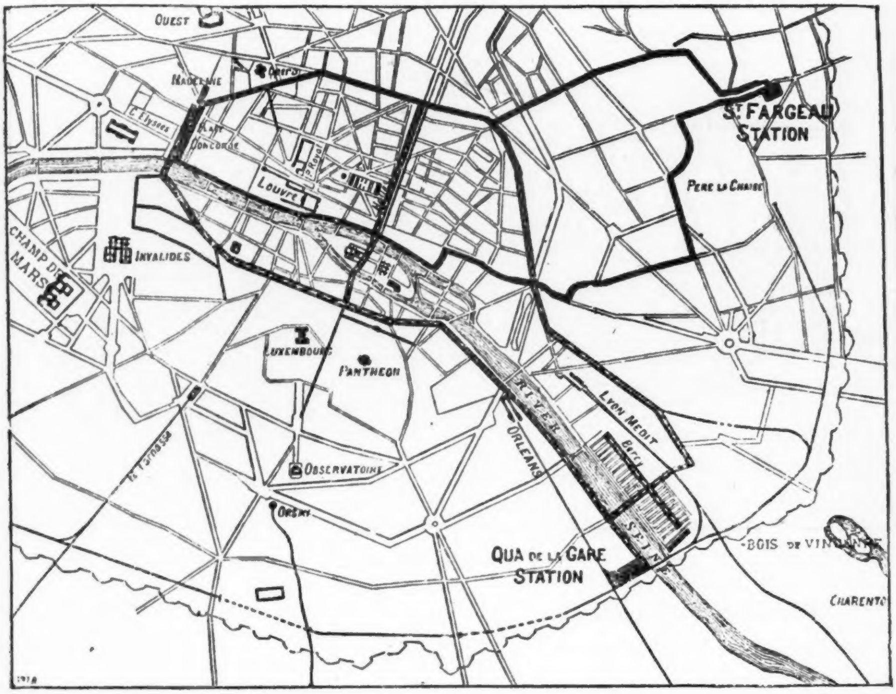
THE MEKARSKI SYSTEM.

land, as the modern tramway was not employed until 1832, at which date, the first street car line for passengers was built on Fourth Avenue, New York. The system was not considered a success, however, until twenty years after, or in 1852, when a second line was constructed, and from this date the system spread rapidly throughout the United States. In 1860, George Francis Train attempted to introduce the present type of street railway into England.

A line was laid on one of the roads of Birkenhead, and the following year a temporary footing was obtained within the suburbs of London. Owing to opposition created by prejudice, the system was extinguished for some years, and was not successfully revived till 1868, when by act of Parliament, permission was obtained for a system of horse railroads in Liverpool. Following this there was a rapid development of horse street railroads on the continent and other parts of the civilized world.

The Vincennes-Ville Evrard Compressed Air Tramway.

In 1888, a tramway was constructed from Vincennes to Ville Évrard, and the Mekarski compressed air cars put in operation. The system then employed consisted of a motive fluid, not cold and dry compressed air, but a mixture of air and steam. This was done because it was known that compressed air when expanding produced a strong depression of temperature, the steam in giving up its heat limits such depression, which is the cause of a great loss of power. Air was used under low pressure. A regulator was interposed between the compressed air reservoirs and the engine; (1) a heater that serves for obtaining the motive fluid, and (2) a regulator or expander that serves for sending the gaseous mixture to the cylinders under a constant pressure, whatever be the pressure in the reservoirs. The results obtained show it to be a most economical process. An examination of the figures for several years showed that



PLAN SHOWING AN AIR PIPE LINE IN PARIS.

animal traction cost from 23 to 15 cents per mile, and steam propulsion cost 20 to 15 cents per mile, and compressed air propulsion at Nantes cost less than 12 cents per mile.

The line mentioned is 58 miles in length. It runs through the Bois de Vincennes, passes near Fontenay-Sous-Bois, goes to Nogent-Sur-Marne and Perreux, touches Neuilly-Sur-Marne, and finally ends at the departmental asylum of Ville Evrard. It has gradients reaching half an inch to the foot. This same system had been in operation at Nantes for nine years previous, and satisfactory results had been obtained.

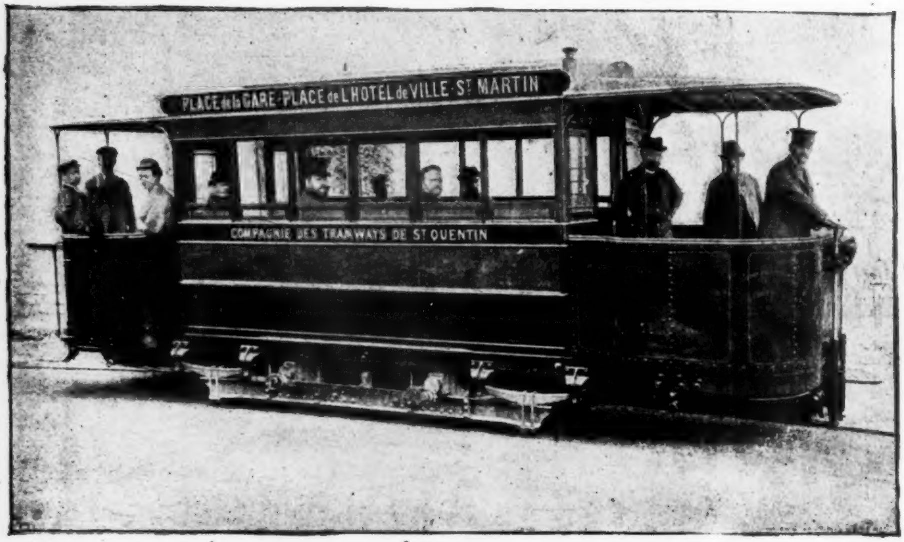
The Popp-Conti System.

The Popp-Conti system which is in use in Saint-Quentin, Angouleme and Lyons, France, is described as follows:

It is a low pressure system and at starting, the tramway is charged with a sufficient quantity of compressed air to enable it to run for four kilometres, after which distance it becomes self-charging, and by the following ingenious device.

Before each waiting station the rails are provided with a pipe which is set in the hollow over which the wheels pass. That causes a smaller pipe to spring from the ground and enter a hydraulic joint placed under the tramway, by which means the receivers installed there are connected with the underground conduit. The amount of compressed air received in a few seconds is sufficient to propel the tramway for a further distance of four kilometres. This done, the little pipe re-enters the ground and is automatically covered by an iron plate, over which men and horses alike may pass with perfect safety.

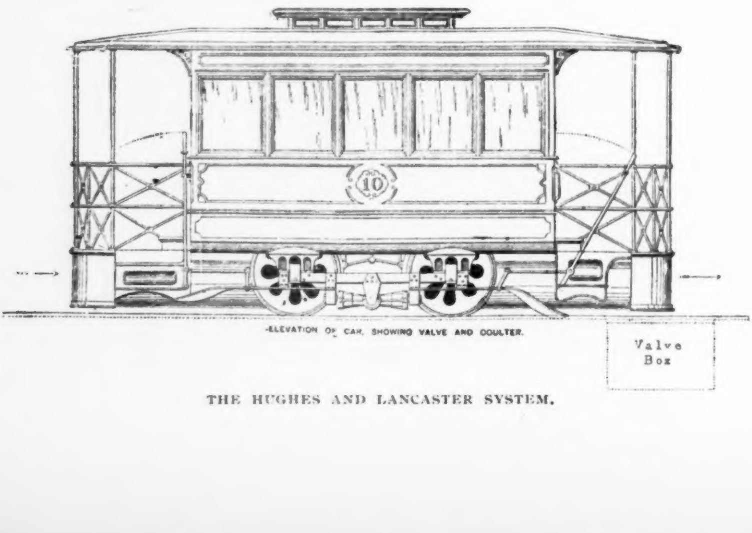
Such prominent engineers as MM. Huet, Boreux, Humblot, Petsch, Monmerquè, &c, who were present at several tests, congratulated M. Victor Popp upon the success of his system.



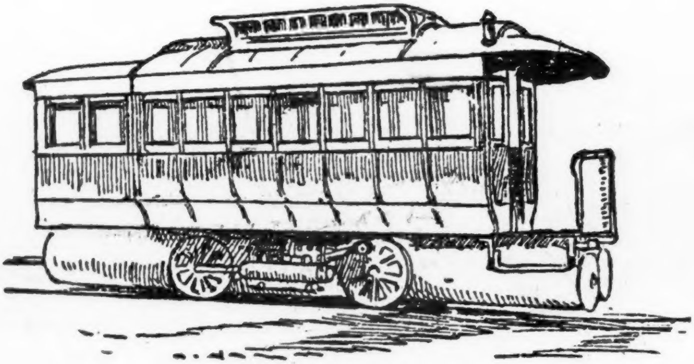
THE POPP-CONTI SYSTEM.

The Hughes and Lancaster Car.

In 1890, Messrs. Hughes and Lancaster, of Chester, England, operated a tramcar by compressed air at a pressure of 155 lbs. to the square inch. The air was carried in vessels attached to the car, and the supply of air was renewed at intervals on the journey by an automatic valve on the car. A corresponding valve is placed on an air main which is laid the whole length of the tramway where the road had heavy gradients, and where the traffic was exceptional they were placed at smaller intervals. Air could be taken whenever required. This mode of collecting energy en route, has its own friends and is said to be economical.



THE HUGHES AND LANCASTER SYSTEM.



THE JARVIS SYSTEM.

The Jarvis Pneumatic Car.

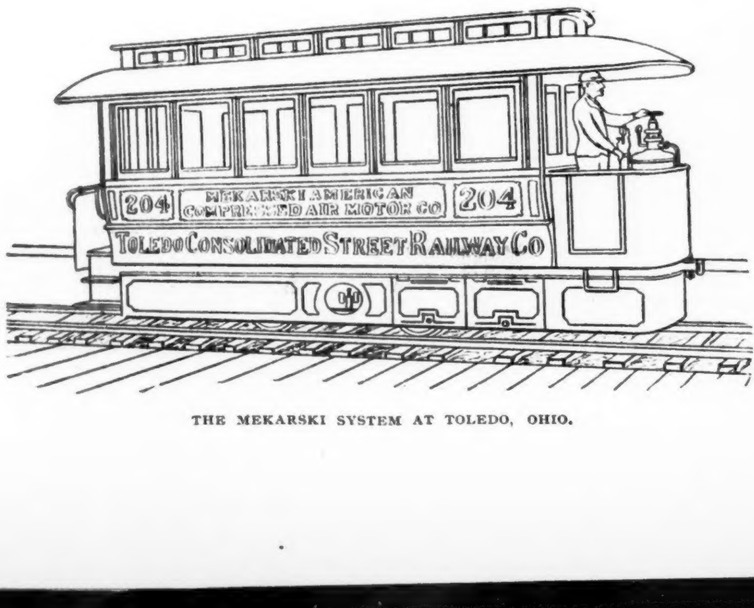
At Detroit, Mich., in 1892, inventor Samuel E. Jarvis made experimental trips with a low pressure car on a mile of track. Air was compressed at one end of the line and was delivered to a 6-inch main which was laid just under the pavement in the center of the track for the full length of the road. The motor got its power from this pipe. The car carried four cylindrical tanks. It was able to run at the rate of fifteen miles an hour.

The tanks were charged at street crossings or other places where it was necessary to make stops.

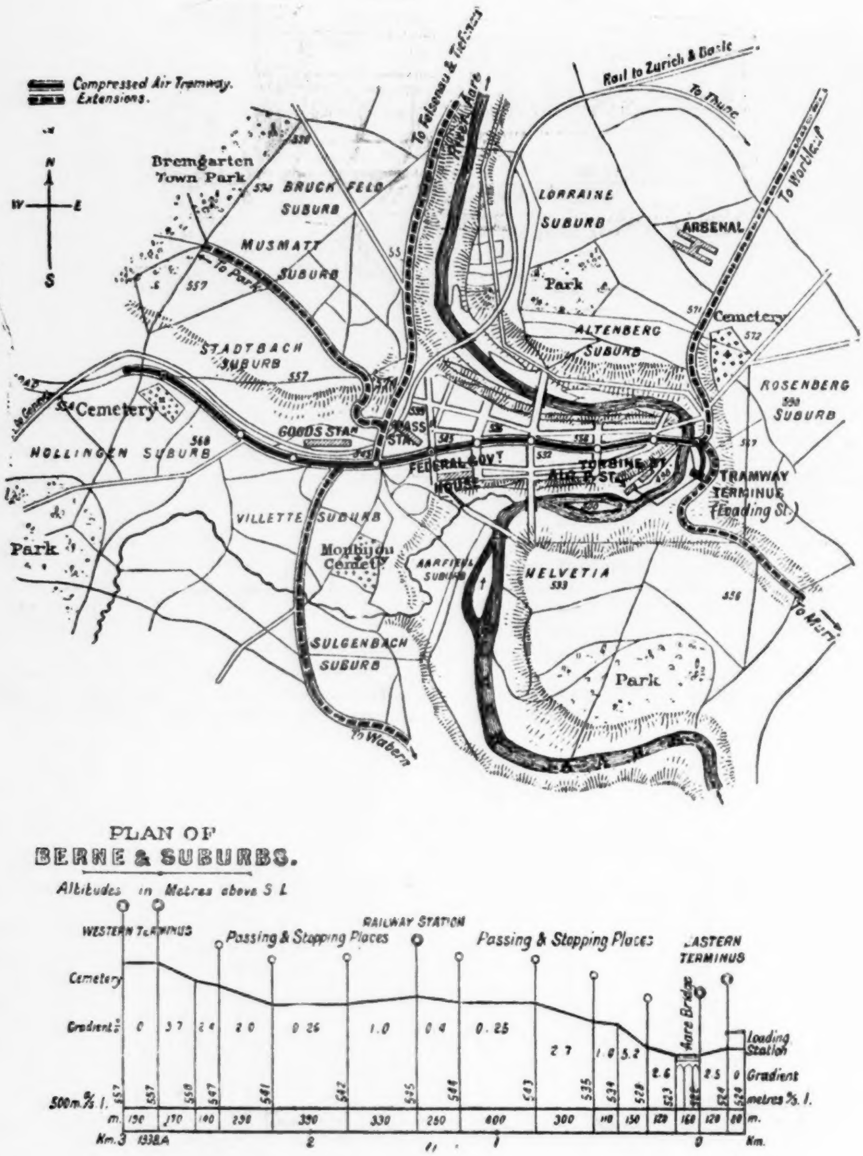
The Mekarski Car at Toledo, Ohio.

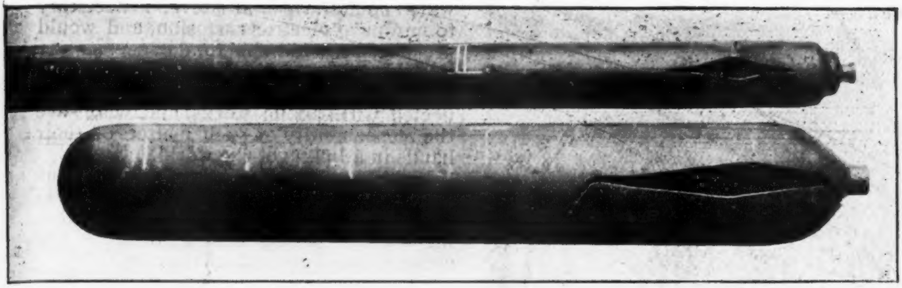
In 1892, the Consolidated Company at Toledo, installed a plant of the Mekarski system. The trial trips were made from the power house along the principal business street of Toledo, and on tracks used jointly by the horse and electric cars, where the traffic was heavy. The car rode smoothly and offered no objectionable features to the public.

The car would run between eight and nine miles without recharging, and was handled with ease and promptness, and all motions were under perfect control.



THE MEKARSKI SYSTEM AT TOLEDO, OHIO.


Compressed Air Tramway.
Extensions.
N
W
E
S
Rail to Zurich & Basle
To Thune
To Worblaufen
To Felsenau & Tiefenau
River Aare
Bremgarten Town Park
BRUCK FELD SUBURB
MUSMATT SUBURB
LORRAINE SUBURB
ARSENAL
Park
Cemetery
ALTENBERG SUBURB
STADTBACH SUBURB
To Park
ROSENBERG SUBURB
Cemetery
GOODS STAN
PASS. STA.
FEDERAL GOVT HOUSE
TURBINE ST. AIR. P. STA.
TRAMWAY TERMINUS (Loading St.)
HOLLINGEN SUBURB
VILLETTE SUBURB
Monbijou Cemetery
AARFIELD SUBURB
HELVETIA
Park
SULGENBACH SUBURB
To Waben
To Muri
Park
PLAN OF
BERNE & SUBURBS.
Altitudes in Metres above S.L.
WESTERN TERMINUS
Cemetery
Passing & Stopping Places
RAILWAY STATION
Passing & Stopping Places
EASTERN TERMINUS
Aare Bridge
Loading Station
Gradient
Gradient
metres %. l.
500m. %. l.
m.
Km.



MANNESMANN TUBES RUPTURED UNDER 5,760 POUNDS PRESSURE.

The Mekarski System at Berne, Switzerland.

The main line of the compressed air tramway of Berne, Switzerland, traverses the town from east to west, and measures 3 kilometres or 2 miles, within which, being a single line, it has eight passing places about 66 yards in length each. The extensions shown in above map practically cover the city, and reaching all the principal points of interest or of commercial importance. At certain points there are rising and falling gradients of 5 to 6 per cent. and this precluded horse traction. Cable traction would have been too costly and the same objection applied to underground electric traction, and the local authorities positively declined to allow overhead trolleys. Traction by electric accumulators was by general consent recognized as a failure. Under these circumstances, concessions were granted to a company using the Mekarski system in 1889 and put in operation.

Tables of cost show that the cost of operating does not exceed 8.9d. per car mile. The number of single journeys made per day of 14 working hours, is 160, equal to about 300 car miles, and the number of passengers in the year 1891 being 3140 per day, or 20 per car journey, Seven motors are required; six are constantly on the line, and two cars are kept in reserve. Their carrying capacity is about 28 passengers.

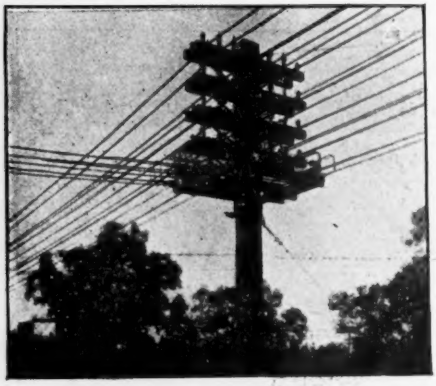
Mannesmann Steel Bottle Test.

The public in general appears to have the idea that using compressed air stored at high pressures on street cars is dangerous. To prove how unfounded is this view, one of the bottles or tubes that is used in street cars was tested to destruction by hydraulic pressure on the 10th of November last, by Chas. G. Eckstein & Co. of New York, at the works of Messrs. Watson & Stillman of this city. Prof. Jacobus of Stevens Institute, conducted the test the results of which are given below. Among those interested present were Mr. Alfred Mannesmann, president of the Mannesmann Cycle Tube Co., Adams, Mass.; Frank Richards, of the "American Machinist;" John J. McCutcheon, Ass't Engr. American Air Power Co.; Rudolph Albert, Sup't Consumers Brewing Co., and Dr. Wm. Mettenheimer.

The bottle was marked off into 7 equal parts and the measurements taken without pressure beginning at the bottom, were as follows: 2′ 5 1-16″, 2′ 5 1-16″, 2′ 5 1-16″, 2 5⅛″, 2′ 5 3-32″, 2′ 5 3-32″, 2′ 5 1-32″ outside diam. respectively. Length 5′ 6⅛″ over all between perpendiculars.

Under a pressure of 2500 lbs. the greatest expansion was a little over 1-16″; at 4000 lbs. 3-32″. When this pressure was removed the bottle returned to its original measurements. At 4350 lbs. the greatest expansion was ⅛″; at 4550 lbs. 7-32″, and the greatest permanent set noticed was 6-32″.

At 5000 lbs. the length of the bottle had increased nearly ⅛″, and the expansion was 7-16″; at 5280 lbs. ⅝″; at 5730 lbs. 13-16″. The bottle burst under a pressure of 5760 lbs. The fracture was very clean, and not even a minute particle of the metal flew. The fracture extended from the neck a distance of 2′ ¾″ down the side of the bottle.



WIRES IN THE STREET.

Electrolysis.

The consensus of opinion is unmistakably to the effect that electrolysis is a danger that must be taken into consideration when determining the advisability of electric roads. Without discussing the trouble itself, we simply give as references the following authorities who have made investigation of this destructive agent. In the report of the City Engineer of Boston, in 1893, his investigation showed evidence of injury resulting from corrosion caused by the passage of the return current of electric street railways. At the meeting of the New England Water Works Association the same year, C. H, Morse read a paper describing the cause and remedy for electrolysis of lead and iron water pipes. In the transactions of American Institute Electrical Engineers, 1894, J. H. Farnham contributed a very interesting article, proving conclusively that water pipes, gas pipes, and lead cables are being destroyed by electrolytic action due to the track return of electric street car lines. Charles A. Stone and Howard C. Forbes discuss the same subject, as it occured in Boston, with practically the same conclusions in the Journal, N. E. W. Association in 1894. The results of electrolysis and its corrosive action is described by Inspector Stewart, of St. Joseph, Missouri, the same year. It is so evident, that the American Water Works Association appointed a committee to recommend preventive measures, and received its report at their meeting in 1894. A writer in *Cassier's Magazine*, April, 1895, discussed the legal aspects of electrolysis, and determined that electric railways should furnish whatever is necessary to minimize electric corrosion, and would probably be held liable for damage.

The subject has received treatment from city engineers and others who are connected with public works, and who have the responsibility of such matters on their hands in all parts of the world.

Electric traction has proved a dangerous element in municipal underground work. It is a silent destroyer of pipes, and a menace to public health, through the escapement of gas and sewage.

Trolley Currents.

DAMAGE TO THE WATER AND GAS PIPES IN BROOKLYN BY ELECTROLYSIS.

Fresh attention is being drawn in Brooklyn to the danger to the water, gas and other underground pipes through electrolysis, produced through the escape of the electric currents in the ground from the trolley railroad wires. Both the Brooklyn Union Gas Co. and the Edison Electric Light Co. have recently been making investigations with a view to determine the amount of damage to their plants since the trolley lines went into operation, and actions, it is said, may be instituted against the railroad companies. A few days ago it was found that the gas was escaping at a point in Classon Avenue, where the pipe crossed beneath the trolley tracks at right angles, and when taken up the pipe was seen to be eaten away for a distance of two feet by the electric current. The city authorities will probably soon have the whole matter made the subject of an official investigation.

New York Sun, Feb 26, 1897.

Aside from the question of economy of Compressed Air for Street Railways which has been established to a point that is exceedingly favorable, it is quite absurd to attempt to make any statement of so much per car mile or so much per mile. The cost varies according to the different conditions under which the system may have to be applied. For a five minutes service it comes to much more in capital cost per mile than it would for a ten minutes service, and at the same time it costs very much less in working expense per car mile.

Cost of Operating Air Cars in New York City.

It seems especially pertinent at this time to publish a statement of the actual operation and operating expenses of the American Air Power Company's cars that have performed a regular commercial service on the 125th St. line of the Third Ave. R. R. in New York City, since the 3d of August, 1896, with a success unparalled in the history of mechanical traction.

The period elapsed covers the extreme ranges of temperature experienced in this locality, and fortunately also two snow storms of more than ordinary severity, so that the seven months continuous duty on which the following statement is based will meet the conditions incident to any street railway service.

The 125th St. line of the Third Ave. R. R., extends across town from the North River to the Harlem River, the length of the tracks being 10,854 feet, making the round trip 4.11 miles, over which cable cars are operated at intervals of 2½ minutes. Air cars were substituted for two of these cable cars, the schedule calling for 19 round trips each, or 79.09 miles per car; for a daily service of 156.18 miles besides 1.14 miles of switching to and from the car house and street tracks, making the total distance covered daily, 157.32 miles. Each car runs from 12.50 to 16.67 miles on a single charge of air.

The switching referred to is unavoidable in operating this service owing to the arrangement of the car-house in relation to the street tracks, it being some distance from the terminal of the road.

During a portion of the time, only single service was performed, as at present, so that the total average mileage per day from August 3d to March 3d, was 125.16 miles, and the total distance covered, 23,030.5 miles; and the total number of passengers carried, 137,386. The cars have operated every week-day, but are not run Sundays.

The accompanying profile of the 125th St. line shows that the grades to overcome fairly represent average conditions in New York. The grade from Fort Lee Ferry east to the Boulevard being 1.96%, while at the New York Central R. R. tunnel crossing, the maximum grade is 7.7% for a short distance, which is just as difficult to start the car upon as a long grade of the same ascent.

In the following statement of operating expenses, the coal and water items include all that has been used at the compressing plant during this period, and the labor account includes in addition to the operating employees, a night watchman, record keeper, and also switchman for a portion of the time. It must also be borne in mind that the fires are kept under boilers for 24 hours, although the compressor only runs 7 hours daily.

Actual average cost per car mile for entire period—7 months—125.16 miles per day.

Coal	$0.0563
Water	.0103
Oil and Waste	.0013
Power Plant Labor	.1261
Conductor and Motorman	.0608
Repairs car equipment	.0038
	$0.2586

Average present cost per car mile, while one car service performed—78.09 miles per day.

Coal	$0.0675
Water	.0113
Oil and Waste	.0017
Power Plant Labor	.0833
Conductor and Motorman	.0608
Repairs, Car Equipment	.0038
	$0.2284

Average present cost per car mile with two car service—156.18 miles per day.

Coal	$0.0433
Water	.0103
Oil and Waste	.0013
Power Plant Labor	.0833
Conductor and Motorman	.0608
Repairs	.0028
	$0.2018

If the proportion of labor actually utilized in this service is considered, the expense would only amount to $0.1791 per car mile at present.

Present number of employees, six, besides conductors and motormen.

The reason for the present cost of operation being lower than the average for entire period is that the number of employees has been reduced in addition to a less air consumption by the car. The number of employees at present is, however, sufficient to operate a fifteen car service, so that the proportion of labor charges per car mile is still very high.

At a recent conference of several engineers, who investigated the cost of operating the American Air Power Co.'s system in behalf of a street railway now operating

PROFILE SHOWING GRADE ON 125TH STREET, NEW YORK.

a large number of cars at intervals of one minute, it was determined after careful examination, and agreed that for the items above enumerated, the cost per car mile would in no event exceed $0.085, and that with a large equipment of cars in service, like that performed on 125th St., the cost would only be $0.0756 for the same items now costing $0.2018, while operating the two car service. This would make the total operating expense of such a road about 12 cents per car mile.

For the benefit of any who may not be familiar with the operating cost of so small a number of cars by mechanical power, the following data is furnished:

In the recently published report of the operating expenses of 22 electric roads in Connecticut for 1896, the West Shore Street Railway Co., West Haven, is reported as operating precisely the same mileage, namely 4.11, with the same number of cars in service, having however only five employees, and the average cost of operation per car mile is shown as $0.2991.

In the published report referred to, the average cost of operation per car mile of the 22 roads given, is $0.1444; and in the 20 roads having the items of motive power, and line repairs given, the average cost appears as follows:

Motive Power, Average..	$0.02816
Line " " ..	.00270
	$0.03086

The average consumption of free air per car mile for the seven months service of air cars on 125th St., has been 477.7 cubic feet. During the severe snow storm of December 16, 1896, the cars performed the schedule service with promptness and regularity, carrying 20% per cent. more passengers and using 22% more power that the day previous. In comparing results with an electric road in this vicinity, it appears that with 33% less service than the day previous, the load on the power-plant was about 80% greater.

During the last week, the average consumption of free air per car mile was only 414 cu. ft., and many of the trips were made on considerably less than 400 cu. ft.

The actual cost of compressing air to 2500 pressure per square inch, and storing for use in a modern air compressing plant operating with condensing engines including coal at $2.75 per ton, water, at $1.00 per thousand cu. ft., oil and waste, the removal of ashes, labor, repairs and maintenance of power-plant, depreciation, and interest on cost of entire power-plant including buildings, for compressing plants of the following capacities, based on the consumption of 2½ lbs. of coal per hour, per horse power for 20 hours per day, will not exceed the following figures:

Cost per 1000 cu. ft. of free air compressed to 2500 lbs. pressure per sq. in.

Station Capacity.	
500 cu. ft. per minute........	$0.0675
1000 " "	.0571
2000 " "	.0469
3000 " "	.0419
4000 " "	.0394
5000 " "	.0375
6000 " "	.0359
7000 " "	.0342
8000 " "	.0326
9000 " "	.0312
10000 " "	.0300

Responsible parties will guarantee that the cost will be less than stated, and the writer believes that the cost in highest grade plants can be reduced fully 25%.

Assuming the average consumption of air per car mile can be kept as low as at the present time, the average cost of motive power per car mile on the above basis, would range from $0.0124 to $0.027; or an average of $0.0197; and even if 477.7 cu. ft. the same as averaged for the past seven months in regular service, the cost per motive power per car mile, will range from $0.014 to $0.032, or an average of $0.023. Placing these figures against the cost of

motive power as averaged in the Connecticut electric roads for 1896, the results seem to show considerably in favor of compressed air as a motive power.

This cost of motive power, based on 20 hours service, does not represent the lowest cost that is available for the different capacities in the best practice for this reason, that in a compressed air plant having station storage reservoirs for accumulating the air, the engines can be worked at a uniform load at the most economical point of cut-off, for say 16 hours after which the engines may be shut down and the power-plant charges stopped.

At the 125th St. compressing plant, the engine is operated only about 7 hours daily, while the cars perform a 12 hour service from a 7 hour station duty.

The process of operating the compressed air system on 125th St., is as follows:

The air is first compressed by a steam actuated air compressor, which is compounded in three stages from which the air passes through a cooler and dryer and is accumulated in a nest of Mannesmann steel flasks which are all connected in multiple by a series of headers or manifolds, in which stop valves are placed for controlling and confining the air to be stored at a maximum pressure of 2500 lbs. per square inch. A pipe leads from this air storage to the car house charging stand, placed alongside the track, which consists of a copper pipe in three sections, having a controlling valve and flexible joints and a charging nozzle at the end. All the joints and the nozzle are self-packing, so that no leakage has occured in the seven months service. After the car has been connected by inserting the nozzle in a pipe at the side of the car track, the charging valve is opened and contents of the station storage flasks admitted until the desired pressure—2000 lbs. per square inch.—is registered by the car storage gauge. When the charging valve is closed, and a small bleeding valve in the charging pipe opened, permitting the high pressure air in the short length of pipe to escape, at the same time a check valve in the car piping closes automatically preventing any escape of air, after which the nozzle is removed and the car ready for another 17 miles service. The entire time occupied, including connecting and disconnecting in actual daily service, takes less than 2 minutes, and has been done in less than 1 minute in numerous trials.

At the same time the car is being charged with air, another nozzle is introduced to the heater connection, and live steam from the boilers is admitted, until the temperature registered is about 300 degrees Fahrenheit.

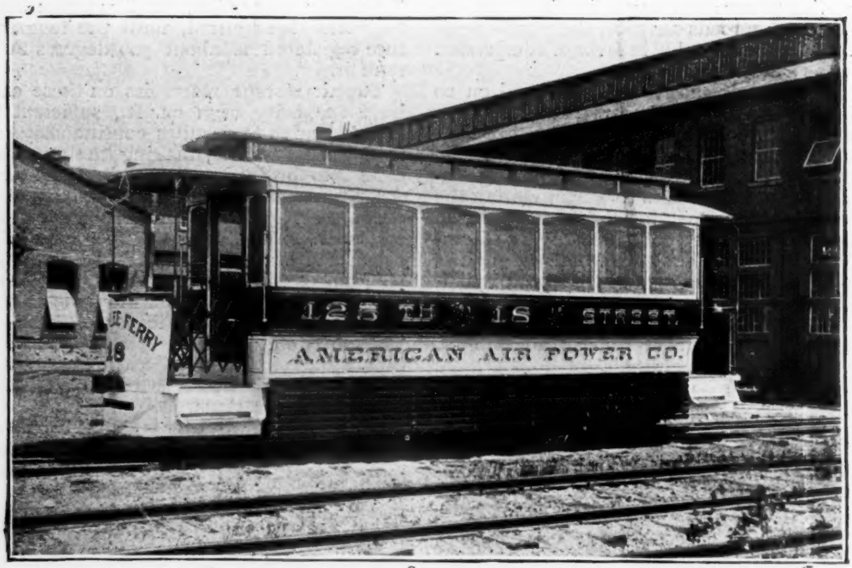
The air storage reservoirs on these cars have a capacity of 51 cu. ft., sufficient to run the car 18 to 20 miles continuously, or from 14 to 17 miles, making the stops incident to ordinary street railway service. A larger capacity could readily be installed on the car, giving it ample power to run 20 miles with a reserve. The reservoirs consists of seamless steel flasks capable of standing a pressure of double that used without reaching the elastic limit of the metal and with no possibility of leakage. They are 9 in. in diameter and of varying lengths adapted to their location under the seats and the car floor. Between the flasks and the motor is placed a small tank containing 6 cu. ft. of water which is heated as before described. The tank is jacketed with non-conducting material preventing external radiation. This provides not only against loss of heat, but also against any perceptible rise in the surrounding atmosphere, so that no discomfort can arise from it.

Numerous trials have proved that the application of heat as employed in this system enables the cars to run nearly double the distance that cold air will carry them.

In operation, the compressed air, after passing through a reducing valve and being lowered to 150 pounds to the square inch (the working pressure), circulates freely through the hot water, and a mixture of heated air and vaporized water passes to the motors, working expansively, the terminal pressure being so low as to cause no sound in exhausting the air.

The motor mechanism consists of two simple, link-motion, reciprocating engines having cylinders seven inches in diameter and fourteen inch stroke, with valves cutting off at from 1-10 to 1-6, and applying the power by connecting and paralled rods direct to the crank pins of the drive wheels which are four in number, twenty-six inches in diameter, running on a wheel base of seven and one-half feet. Upon this four-wheeled truck rests the entire weight of the car and mechanism, evenly distributed upon elliptic springs, enabling the car to pass much more smoothly over bad track and crossings, than an electric car (on which the motors are a dead weight upon the axles) besides being a great saving in wear on the rails at the joints, and on the rolling stock.

The mechanical features of the motors



THE HARDIE MOTOR CAR, 1897.

are substantially identical with those of a steam locomotive, minus fire box and boiler, which in point of perfection in mechanism as a moving power is too well known to need any comments.

The manipulation of the car is simplicity itself, requiring no special skill or training to handle with perfect facility, and capable of being moved in either direction as little as two inches.

It is perfectly noiseless, odorless, and entirely free from any other offensive feature, sending neither smoke nor steam into the air. It responds to the starting and stopping devices with remarkable promptness, operating without any jerks or jars.

This feature of easy and perfect control seems to me to be the most vital point in its relation to the public; as in other respects (freedom from the element of danger to the public as a manifestation of power), its non-hazard superiority is easily demonstrated. The ease and infallibility of control excels that of any other system known to the writer for street railways, and can never fail so long as the car has ability to move.

The car is fitted with specially designed air-brakes of sufficient power, with the high-pressure air always at command, to set the wheels instantly if desired, by a single wrist movement of the motorman. Upon releasing the brakes there is an entire absence of noise of any kind from either the mechanism or escaping air, which is so noticeable and annoying with air-brakes generally.

The same lever that releases the brakes, operates, by a slight advancing movement on the quadrant to open a by-pass admission of the compressed air, directly into the cylinders of the motors, enabling them to start easily and positively, whatever the position of the cut-off valves may be, and preventing any possibility of being stopped on "dead centres," after which the throttle is opened. This ability to start so promptly and surely under all conditions, is a feature possessed by no other reciprocating motor, and the inability to overcome this difficulty has been one of the principal causes of failure in kindred types of motors heretofore exploited. The application of the principle of a by-pass admission of air into the cylinder, seems to be confined exclusively to the motors of the General Compressed Air Company, and is of the greatest importance, materially affecting the economic operation of the motors, aside from assuring their infallibility in starting.

The entire system embodying the mechanism and method of developing and

applying the power, for the purposes under consideration, consists of simple, practical devices, operating on the most approved principles, from which all offensive and uneconomic features have been eliminated and better fulfilling the requirements of an ideal means of street car propulsion than any other within the writer's knowledge.

EDWARD E. PETTEE.

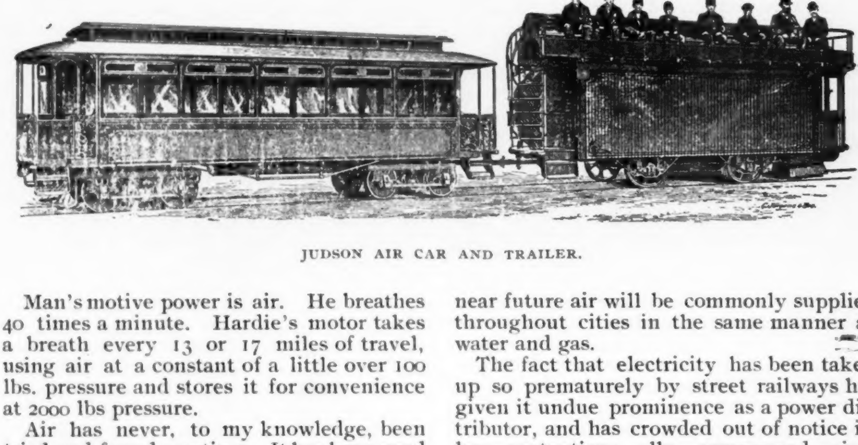
March 15, 1897.

Air Power Reflections.

Compressed air is speaking daily for itself, through the various machines in which it is used. The physical part of man is itself only a machine which uses air. Sir John Lubbock says, "Men, like trees, live in great part on air;" and Oliver Wendell Holmes says, "Laughter and tears are meant to turn the wheels of the same sensibility, one is wind-power and the other is water-power."

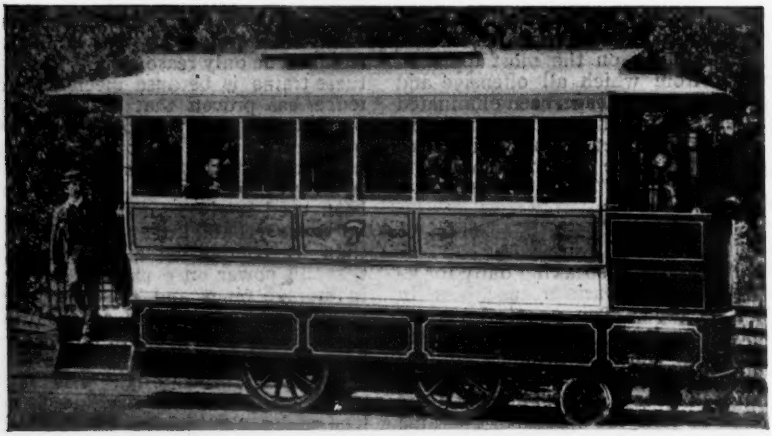
Man's motive power is air. He breathes 40 times a minute. Hardie's motor takes a breath every 13 or 17 miles of travel, using air at a constant of a little over 100 lbs. pressure and stores it for convenience at 2000 lbs pressure.

Air has never, to my knowledge, been tried and found wanting. It has been used from the earliest days more prominently to propel ships and work wind-mills, and for other purposes, but its first general application, which brought it prominently to the public notice as a mechanical force, was its adoption in the Westinghouse and other air brakes. It was strange that this did not suggest the thought that what was good to stop the train was equally good to start it. And it is a curious fact that even at this late date the electric trains upon the elevated roads in Chicago, which are propelled by electricity, use the current from the rail at the moments of rest to work an air pump to store air to stop the train. The only reason air is used to stop these trains is because mechanical experience has proven that there is nothing better than air for that purpose, and in my opinion, the only reason why air is not used to start the trains is because it has never yet been tried. Wherever air has been used it gives satisfaction. There is no more economical power distribution than by compressed air, for the reason that this power once made it can be saved in storage pipes and reheated at time of using, which gives an advantage over electricity. In storing air in pipes and reservoirs there is little waste and scarcely any depreciation in material. The fact that air is good for small machines is equally true of large machines, and its uses are being extended from day to day, until there are many who believe that in the near future air will be commonly supplied throughout cities in the same manner as water and gas.


JUDSON AIR CAR AND TRAILER.

The fact that electricity has been taken up so prematurely by street railways has given it undue prominence as a power distributor, and has crowded out of notice its less pretentious ally—compressed air—which has been gradually introduced into service upon the steam railroads, in shops, mines and general mechanical work, until it is a question whether there is not fully as much power conveyed to-day by compressed air as by electricity, though the air is used in out-of-the-way places where its growth has not been remarked.

My attention was first directed to compressed air in 1888 at the Minneapolis Exposition, where I saw a small car 22 in. long and 8 in. wide, which was operated by levers placed in a trench between a small



HARDIE CAR NO. I.

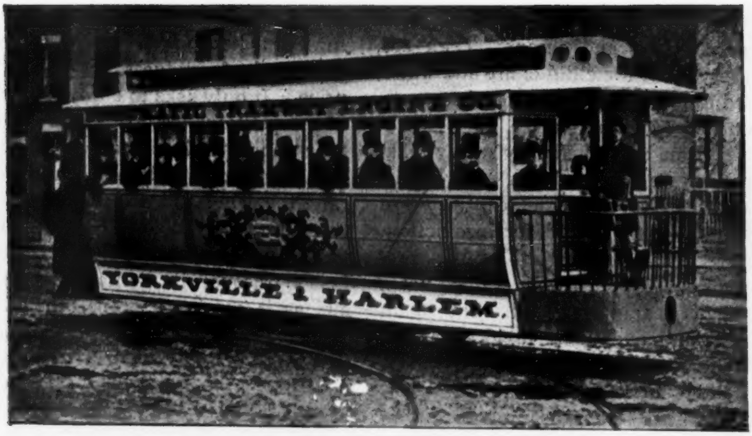
circular track laid out on a table. Movement was imparted to the car by a lever which seized a triangular cam, and in making half a revolution passed the car on 16 feet. This cam was attached to an apparatus, which was connected to the car through the slot, and when one lever let go another lever took hold, and so on. What surprised me was that the air power which operated the cylinders that moved the cam levers was conveyed in a lead pipe not larger than a lead pencil, and the hole conveying the air was no larger in diameter than the lead of an ordinary pencil.

On this car I saw a man who weighed 229 lbs., and who was carried around this track at speed. To hold on to the car it was necessary for him to kneel down with his feet hanging over one end of the car. This exhibition suggested thoughts of the power of air, which I had only considered in a general way up to that date.

In 1891, principally through the efforts of a party of friends in Chicago, a geared motor car was built at Pullman and a charging device constructed by which the car was automatically charged while passing over a specially constructed pit. Air in this motor was only used at 190 lbs. pressure, and the motor travelled 4½ miles with one charge of air. These patents are now all owned by the American Air Power Co., but Robert Hardie's experience has proved that air at high pressure is easily and safely handled, and possesses many commercial advantages which recommend it above the use of low pressure.

During the construction of the World's Fair Buildings at Chicago, a proposition was made by the parties interested with me at that time to construct the intermural railroad in the fair grounds, and operate it with compressed air. The proposition was to charge only 5 cts. fare, and divide the profits after the structure was paid for. The electric people, however, controlled the situation and made a contract to charge 10 cts. fare and give the World's Fair people half from the start, which was more to their liking, and therefore compressed air was turned down, or it would have made its advent as a motive power in this country at an earlier date than it has. Subsequently I had the good fortune to form the acquaintance of Mr. Robert Hardie, whose knowledge and practical experience in the use of compressed air at high pressures, and whose ability as a mechanical engineer impress all who come in contact with him, and are borne out by the great merit of his devices I was much impressed by Mr. Hardie's plans, and was one of the humble instruments in bringing together the combination which joined in putting Mr. Hardie's inventions before the notice of the public.

The merits of Hardie's inventions class him in the foremost rank of the inventors of this century. All of his promises have been more than fulfilled, and his knowledge



HARDIE MOTOR, 1879.

and experience were the one thing necessary to perfect the motor up to the severe requirements of the street railroads of the present day. Motors constructed under his supervision have been practically tested by the combination represented by the American Air Power Co. for the last three years, and latterly two of them have performed daily schedule on 125th Street since August 3rd, last. In every respect they have fulfilled the most sanguine expectations, indeed surpassed them, and two of them have travelled about 24,000 miles and carried about 140,000 passengers without serious delay or accident.

Compressed air in this field proves itself equal to any and all emergencies. It is nature's prominent force, which she uses to stir the heavy waters of the ocean and prevent their stagnation, or to perform lighter service, such as to carry seeds. It is the natural ally of steam to distribute its force. It is not as wasteful as electricity nor as destructive. It is one of nature's vehicles of motion. What can man do better than to imitate nature?

HENRY D. COOKE.

The Anniversary of "Compressed Air."

In this number we set forth in as brief a manner as possible, a complete record of historical events concerning air power for street railway traction. The many attempts to gain recognition for compressed air as a traction power have been met with more or less suspicion or apathy.

It seeks to be a competitor of other great powers and it certainly deserves that consideration. Steam and electricity have earned an honorable place for their good service. Compressed air is also capable of good service, and the more good things we have to choose from the less danger there is of being deceived.

We are indebted to Mr. J. S. Hickey, superintendent of the Anaconda Copper Mining Company, for the following information in regard to Whitewashing Machines.

David Paterson, foreman of the U. P. R. R. shops, Salt Lake City, Utah, is the inventor of a whitewashing machine to be used with compressed air, and it is first-class.

Parties interested in these machines would do well to communicate with Mr. Patterson at the above address.

Earth, air, fire, water, electricity, contend which shall render the greatest service to man and enjoy the foremost place in the continual triumph of nature and art. In the single matter of locomotion, earth first was foremost, and man trudged, rode and drove. Then water had its turn, and man paddled, rowed, sculled, drifted, or with earth's aid, was punted or pulled.

Then air lent a wing, and the sail carried him across gulfs and oceans. Then fire, or rather steam, the child of fire and water, enabled him to beat the winds and currents, first on water then on land.

At this time we can hardly see by what infatuation we land lubbers allowed the stormy ocean to take the lead of *terra firma* in the use of steam for locomotion. We were actually laughing at the prejudices of old skippers, when we had not a thought of steaming by land. But steam came on land and made rapid advances, and it now almost encircles the globe. Electricity appeared a dominating spirit, whose incipient strengths no man knows But it stands an accomplished fact.

Now comes a new move, and no man can foretell the end, though it begins timidly and awkwardly. Air is now the performer. It comes upon the scene with much modesty, as if knowing itself to be suspected of wildness, treachery and caprice. It only asks to enjoy the privileges of competition. It operates in strong steel tubes and stately carriages. It wants the bridle not the whip. We have only to raise the wind and the process is easier in these days of mechanical perfection. The wind once raised it, will go as we direct. It is a prisoner in vaults of safe deposit, and as it escapes it propels the car. It is so simple that when the system is once put in operation, everybody will ask why this has not been done before. Air power has been held in abeyance, but it must come to the front. These are not times of depressed engineering, but an era of enlightenment, and of knowing a good thing when you see it.

THE PULSOMETER STEAM PUMP

"The Contractor's Friend."

OFTEN IMITATED—NEVER EQUALED.
OVER 20,000 IN USE.

Recent Important Improvements.

The Handiest, Simplest and Most Efficient Steam Pump for General Low Service Mining, Quarrying, Railroad, Irrigating, Drainage, Coal-washing, Tank-filling, Paper Mill, Sewer and Bridge Contractors' Purposes, etc., etc.

Muddy or gritty liquids handled without injury to the Pump.

PULSOMETER STEAM PUMP CO.

Catalogue on Applica ion. **Correspondence Solicited.**

135 GREENWICH STREET, NEW YORK.

ANDERSON PIPE CUTTING TOOL.

. , . . Cuts 1½ to 24 inch. Pipe. . . .

CONTRACTORS' SUPPLIES

OF EVERY DESCRIPTION.

C. H. TUCKER, Jr.

135 GREENWICH ST., NEW YORK.

WRITE FOR WHAT YOU WANT.